



National Aeronautics and
Space Administration

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Subcommittee on Space and Aeronautics

Committee on Science

House of Representatives

Statement by:
Daniel S. Goldin
Administrator

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Mr. Chairman and Members of the Committee:

Our Nation's space program is facing a serious and growing challenge as exorbitant launch costs consume our valuable resources and limit achievements in space science, exploration, and commercial development. It has been 25 years since the United States developed a major new launch vehicle or rocket engine. Serious consequences await this Nation if Government and industry do not bring their respective strengths to bear on geometrically advancing U.S. national launch capabilities over the next decade. Both Government and industry have important and changing roles in this vital effort, centered around the absolute necessity for investing now in the technology needed to safely reduce the cost of access to space beginning early in the next century.

I would like today to outline NASA's role in revitalizing national space launch capabilities and how we are working with industry in mutual efforts to rebuild America's global leadership in space launch.

The Consequences of High Launch Costs

Mr. Chairman, access to orbit today costs roughly \$10,000 for each pound of payload. This enormous expense is at least ten times too much, and is choking off the scientific and commercial potential of our national space program.

Such high cost, for example, means tightly-rationed access to the unique properties of orbital space, reducing the abundant promise of scientific, environmental, and commercial applications which enrich our quality of life on Earth. High cost means fewer missions of deep-space exploration that project America's pioneering spirit and expand our knowledge of the Solar System; and it means profound questions go unanswered such as the existence of life on other celestial bodies. NASA hopes soon to be launching as many as 14

smaller science missions per year. But we cannot afford \$20-25 million per launch, or up to \$350 million annually just for small payload transportation alone.

High cost also cripples the nation's payload development community. Commercial suppliers from the communications and Earth remote sensing industries are telling us the cost to orbit must come down to \$1,000 per pound to be competitive on the world market using U.S. launch vehicles. Moreover, payload production costs are dropping sharply without corresponding decreases in launch costs. For example, the smallest U.S. launchers today cost over \$15 million--too much for university-built payloads costing only \$1-4 million.

Finally, the high cost of U.S. space launch also means foreign competitors are gaining market share. U.S. launchers, preeminent up until the 1970's, now carry only about 30% of the worldwide commercial launch market. The Russians have superior technologies in certain aspects of propulsion. The Europeans have overtaken us in commercial space launch using more modern expendable launchers. The Japanese are moving up fast. For too long, we have acted as though orbital space was not an important international commercial marketplace. We must learn from these mistakes as we move forward.

To summarize, U.S. access to space is so expensive it is a growing obstacle to mission frequency, creativity, and risk-taking -- the very attributes necessary for pioneering a new frontier, both scientifically and commercially. This erodes the Nation's launch industry and balance of trade, costing us thousands of high-value jobs. Our national space launch capability should be a springboard for-- not a dead weight on-- the Nation's economic competitiveness and well being. This Nation must--and can-- achieve radical reductions in the cost of access to space, do it in years not decades, and do it without sacrificing safety and reliability. This is the challenge facing us as we enter the next century, but we must act now if we are to overcome it then!

The Need To Leapfrog Current Launch Systems

Achieving affordable launches will require cost reductions approaching an order of magnitude--e.g., \$40 million for launches now costing \$400 million. Such sharp reductions across all payload classes will not be simple or easy.

Such cost reductions cannot be achieved through modernization of our current expendable launch vehicle (ELV) fleet. The Delta-, Atlas-, and Titan-class ELV's are rooted in the technology of the 1950's and '60's. They were

developed originally as suborbital ballistic missiles and only later converted to space launch. Although the industry has invested over \$1 billion in upgrades to meet Government and commercial requirements, technical limits are being reached. Infrastructure supporting these systems is costly to maintain, processing and manufacturing continue to be labor intensive, and the aerospace industry contraction is increasing the rate of obsolescence in sub-tier suppliers.

Yet, we remain heavily dependent on ELVs to orbit U.S. scientific, technology, military, intelligence, and commercial payloads. They are aging systems, with outmoded tooling and manufacturing, and we operate them on borrowed time.

Likewise, the Space Shuttle--as valuable and versatile as it is--costs about \$3 billion per year, or about a quarter of NASA's budget. Our Shuttle team has done a superb job in reducing costs to current levels, and are finding additional reductions without sacrificing safety.

As a near-term remedy, the Department of Defense is leading a necessary effort aimed at upgrading the national ELV fleet, called the Evolved Expendable Launch Vehicle (EELV) program. At the same time, NASA is pursuing near-term upgrades to the Space Shuttle system and looking at ways to privatize the entire operation. In the private sector, several small commercial launchers are being developed, however, reliability has been a problem and costs, while lower, remain high. These are fitting near-term measures, but, the intrinsic configurations and support requirements of these systems limit achievable cost reductions and performance gains to moderate levels. Although such evolutionary gains are crucial as a bridge to the ultimate improvements needed, they are in themselves not enough for the space launch requirements of the 21st century.

Revitalizing U.S. Launch Capabilities-- The Reusable Launch Vehicle Technology Program

NASA's primary space launch role is to develop and demonstrate pre-competitive next-generation technology that will enable the commercial launch industry to provide truly affordable and reliable access to space. This in turn should enable the U.S. to recapture leadership in worldwide commercial space transportation in the early decades of the next century.

Accordingly, NASA and major U.S. aerospace companies have embarked on an urgent and unprecedented partnership aimed at attaining radical improvements in launch system cost and performance. This is the goal of NASA's Reusable Launch Vehicle (RLV) technology program and the Advanced Space Transportation (AST) technology program.

NASA's RLV program consists of several phases: systems engineering and concept analysis, ground-based technology development, and a series of flight demonstrators--the DC-XA, the X-34 small demonstrator, the X-33 advanced technology demonstrator, and perhaps other future experimental vehicles depending on the technology needs or opportunities that emerge. All vehicles will be suborbital, but together will be aimed at advancing the state of the art in launch technology to substantially reduce the risk associated with developing a full-scale operational RLV.

To optimize the respective strengths of Government and industry, NASA is using an innovative management strategy centered on industry-led cooperative agreements. Government participants such as NASA's space and research centers are acting as partners and subcontractors, performing tasks chosen by the industry leaders and utilizing the specialized expertise and facilities of the Government.

As directed by the President's National Space Transportation Policy and subject to decision criteria agreed to with OSTP and OMB, the RLV program will face two major Government and industry decision points--the first in just a few weeks and the other around the end of the decade. The first decision will relate to whether the underlying technologies are sufficiently advanced to proceed with building the X-33 flight demonstrator. Approval is not a foregone conclusion, although we are determined to meet this challenge.

An extensive, independent study has just been completed by a panel of the National Research Council's Aeronautics and Space Engineering Board (ASEB) validating our development, test, and analysis programs in reaching this important milestone. Also, the NASA Advisory Committee, tasked with an independent verification of the criteria, has determined that the criteria have been met and recommended that we proceed with development of the X-33.

The second decision will be made after X-33 ground and flight tests, when Government and industry will consider whether full-scale development of an operational RLV should be pursued. At that point, if industry and the capital investment community are not satisfied that the technological risk is low enough to proceed to full-scale development, we in NASA will press on with RLV technology work to do what needs to be done. For example, the X-33 may require further testing, or a follow-on vehicle to the X-33 may be needed to prove ultimate feasibility.

Breakthrough Goals of the RLV Technology Program

NASA is well on its way to demonstrating the viability of a reusable launch vehicle. Briefly, there are six RLV parameters to be demonstrated:

- **Reusability** ensures that engines, structures, tankage, and other components do not require frequent, costly, and time-consuming change-out, disassembly, inspection, and refurbishment. This implies well-tested margins on such factors as temperatures, pressures, seals, joints, and spin rates.
- **Operability** means not waiting for months between flights; launches will be possible in a matter of hours or days, using health monitoring systems that will indicate which components need attention and which do not. Maintenance will be modularized for easy servicing. Ground crews will be numbered in the dozens rather than thousands. Launch and landing parameters will not be as sensitive to weather constraints like wind velocity and precipitation.
- **Reliability** requires deep knowledge of all systems and their limits in all regimes of operation. For example, advanced components such as graphite composites require new ways of testing and health monitoring that are very different from conventional aluminum structures. Advanced health monitoring systems will provide unprecedented structural and propulsion status information. Our goal is .999 reliability rather than the current .95 that insurance companies use to establish coverage costs for commercial vehicles.
- **Safety during abort** of launch and all phases of mission is an RLV requirement, including the capability to return to original launch site. Transatlantic abort sites will no longer be needed, saving operational costs and manpower. Safety is paramount and will be addressed in all phases of design, development, and operations.
- **Mass fraction** means the launch weight of the vehicle must be composed of 90% or more propellant without sacrificing reusability, operability, and reliability. This is technically challenging, but improved mass fraction is critical for achieving our goal of \$1,000 per pound of payload.
- **Affordability** is a function of each parameter above, measured by cost. Reusable composite tanks are expected to be more affordable than jettisoned aluminum tanks over the life of the vehicle. Fast turnaround flights made possible by designed-in low-maintenance requirements translate to lower costs. High reliability, to be established during the flight demonstration phase, can substantially lower insurance costs, and thus the

per-flight cost of each vehicle and payload. Eventually, at 1-2 flights per week, huge savings can result that also translate into increased U.S. global competitiveness.

The RLV's Enabling Technology

The RLV technology program is now in the early stages of ground and flight demonstrations aimed at progressively establishing the necessary technology verifications that will enable commitment to the RLV's revolutionary new space launch system early in the next century.

NASA is confident that the RLV program will succeed even though the National Launch System (NLS), National AeroSpace Plane (NASP), and other past attempts failed. One reason is that our approach is not solely Government-directed; the program benefits proactively from the close-in, creative know-how of our aerospace partners. And, we are not attempting too much too soon, such as NLS- and NASP-type flight regimes ranging from zero to Mach 25 in early test vehicles. Revolutionary technology must be developed incrementally. At the same time, we are building on a variety of technologies salvaged from these past efforts, as well as from development of high-performance military aircraft, the Space Shuttle, the New Millennium spacecraft program, and even commercial airline research.

NASA's RLV technology program's approach is to "design a little, build a little, test a little, fly a little"-- in a phased, logical progression all the way through ground tests and demonstration flights on the DC-XA, X-34, X-33 and beyond.

The DC-XA. New technologies are already undergoing flight demonstrations on the advanced version of the DC-X, called the DC-XA. For example, the DC-XA is flight testing the first-ever large-scale composite hydrogen tank, a new lightweight aluminum-lithium oxygen tank, and composite fuel lines, joints, and valves. The vehicle is now at White Sands Missile Range where three flights were recently and successfully completed. The third flight followed the second flight the very next day.

The X-34 Small Reusable Demonstrator. The X-34 vehicle will demonstrate technologies necessary for a reusable vehicle, but will not be a commercially viable vehicle itself. This allows the X-34 vehicle to be more effectively designed as a flight demonstrator test bed and to close the performance gap between the subsonic DC-XA flying in the spring of 1996 and the 15,000-17,000 ft/sec X-33 flying in the spring of 1999. This has been, and remains, NASA's top priority objective for the X-34.

It should be explained that the initial X-34 effort combined NASA's need for

early technology demonstration with industry's need for a commercially viable small launcher. Unfortunately, our industry partners determined that the current economic viability of the program could not justify their investment and they withdrew. However, NASA's objectives for the X-34 to be a technology demonstrator and pathfinder for X-33 remain unchanged.

After completion of its first flight series, the X-34 vehicle could be modified to demonstrate the more advanced technologies coming out of the Advanced Space Transportation Technology program (see below). This modified X-34 would benefit from being comparatively small, thereby lowering the expense and risk of demonstrating the technologies, and making their integration into the vehicle less costly. A low-cost X-34 demonstrator can increase the scope and aggressiveness of flight demonstrations, thus increasing the return to the RLV program.

The X-33 Advanced Demonstrator. Building on ground-based testing as well as the DC-XA and X-34 flight tests, the X-33 program is aimed at integrating and testing advanced component technologies necessary to move to a full-scale RLV.

The X-33 advanced demonstrator will bring these technologies together for the first time in a proof-of-concept demonstration of the feasibility of a single-stage-to-orbit (SSTO) launch system. The SSTO approach offers the greatest potential savings and performance of any configuration, as measured by the parameters of reusability, operability, reliability, affordability, safety, and mass fraction. By striving for SSTO, NASA is pushing the technology envelope to the maximum in order to maximize the potential benefits of the technology development program. However, should SSTO prove infeasible, the great majority of research will be applicable to lower-performing multi-staged vehicles.

Technologies to be integrated and demonstrated by the X-33 program include:

- Lighter, reusable cryogenic tanks;
- Application of New Millennium micro electronics (Avionics on a Chip) to the RLV for vastly improved reliability and vehicle health management;
- Advanced Thermal Protection Systems to achieve lighter weight, durability, and low-cost maintenance;
- Ground and flight operations techniques that will substantially reduce turn-around time and other operations costs for the RLV; and
- Propulsion to reduce the development risk for the RLV engine and prove

the necessary operability;

The fast-track development of the X-33 vehicle precludes flying the engine that will be used on the operational RLV. For this reason, in parallel with the X-33 program, development and ground testing of orbital insertion engines will proceed that will enable the level of reusability, operability, and thrust-to-weight requirements necessary for a full-scale RLV.

Beyond The RLV's Technology Goals-- The Advanced Space Transportation Technology Program

Continuing the revolutionary advancements in space access that we expect from the RLV Technology Program, the Advanced Space Transportation (AST) technology program will focus on a broader spectrum of technological advances with the potential to reduce costs well beyond RLV goals. It aims at a cost to orbit measured in hundreds not thousands of dollars per pound. The AST program has been structured in three key elements; (1) advanced reusable propulsion technology, (2) small payload launch technology, (3) and advanced space transfer technology. Each element will address a recognized need for near- and long-term reductions in space launch costs. Funding for AST is planned for FY 1996-97 with outyear budget levels to be developed .

The first element, advanced reusable propulsion technology, will focus on significantly increasing rocket propulsion performance margins to allow for longer life and reduced maintenance over planned RLV systems. Revolutionary propulsion systems, such as rocket-based-combined-cycle or combined air breathing and rocket propulsion designs, augment rocket systems with air to significantly enhance overall system performance, reduce vehicle size, and improve operational margins. This technology holds the promise of airline-like operations but is higher risk than those being considered for the X-33 and require further significant technological advancement.

A near-term focus of this activity is development and ground test of critical combined cycle components by 1997. Possible follow-on phases will concentrate on component and integrated systems development and demonstration necessary to reduce the risk associated with combined cycle rocket-based propulsion. A system flight demonstration is being studied for the turn of the century. Even if these systems do not mature in time for inclusion in an initial operational RLV, investment in this area is crucial for the longer-term future of space transportation.

The second AST program element, small payload launch technology, focuses on a segment of NASA's launch requirements not addressed by the RLV program. This element focuses pre-competitive technology activities on

dramatically reducing the cost of launching payloads of 500 pounds or less. This technology will enable the eventual commercial development of small payload launch vehicles and will utilize non-traditional suppliers, commercially available parts and commonality among components to realize production rate cost advantages.

Investments will also be made in innovative design for low-cost manufacturing and systems engineering which will lead to space transportation hardware that does not require the highly specialized, labor intensive manufacturing and operation of current space transportation systems. For example, current cost estimates for a small launcher liquid oxygen/kerosene propulsion system are \$3-4 million. This AST element will demonstrate technologies aimed at engine systems costing \$300-400 thousand and will begin ground testing of priority technologies by the end of 1997.

The third AST element, advanced space transfer technology, is aimed at increasing the efficiency and reducing the cost and trip time of current orbital transfer systems. Transfer systems which increase transportation efficiency by more than a factor of two seem achievable within five years. Payloads requiring delivery to geosynchronous equatorial orbit could be launched by smaller, lower cost launch systems or share space with other payloads on larger launch systems. Reduced trip times will shorten the time that teams will be required to remain in place to execute missions. Exploration initiatives like the New Millennium Program are focused on miniaturizing spacecraft, but cost advantages will be weakened unless spacecraft propulsion reaches efficiencies which allow an order of magnitude reduction in size and mass. The near-term focus of this effort is a solar thermal propulsion demonstration in orbit by 1998, and an electric propulsion application on the initial flight of the New Millennium spacecraft.

Commercial Launch Strategy -- A Paradigm Shift in Progress

During Apollo, the government and industry worked together in a partnership that moved this nation forward to historic accomplishments in space with untold benefits on Earth. We are rediscovering the spirit of Apollo -- that a government and industry team working together is the right stuff, and advanced technology will have nearly immediate potential for terrestrial applications. We are using innovative methods-- from the shop bench, to procurements, to policy changes-- in order to prove the viability of this approach. We are encouraged by the results so far.

At the same time, we are concerned over the apparent lack of commitment of many industry leaders to invest in advanced technologies needed for long-

term success. Past technology efforts have been focused on short-term needs and have lacked the vision and investment needed to help maintain our nation's leadership in space launch.

Changing Roles of Government and Industry. The space launch industry must realize that the days of large NASA contracts to develop, build, and operate launch systems are over. NASA is becoming a customer not a manager or dominator of the launch industry -- a relationship which in the past contributed to noncreative dependency by the industry on the Government. NASA now buys and will continue to buy launch services. And NASA has the responsibility to be a smart buyer.

This means both the burden and the opportunity of developing successful and profitable operational vehicles and systems is shifted to the aerospace industry. Companies with vision who demonstrate creative technological excellence at low cost and risk will beat their competition and will win NASA's launch business in all payload classes.

At the same time, NASA's role will continue to be development of pre-competitive technologies to radically reduce space launch costs, working closely with industry to optimize development funding and respective strengths. This includes joining forces with companies through cost-shared cooperative agreements to focus and maximize results. NASA's RLV technology program is based on this approach, and is driving leapfrog component technologies toward readiness for pre-2000 flight demonstrations and post-2000 commercialization.

Real commercialization of the space launch industry depends on NASA and industry working closely on pre-competitive technologies, and industry picking up and running with development of the operational launch systems. This paradigm shift will, we believe, become the future norm for most of the U.S. Government's space launch business during the operational RLV era. This shift in Government-industry relationships will also position the commercial launch industry to regain preeminence in the global marketplace since it incentivizes companies to develop, build, and launch vehicles that will outstrip foreign competition.

Foreign Involvement. At the same time, the space launch business--like business everywhere--is becoming more internationalized. U.S. and foreign launch companies are increasingly seeking to maximize their competitive position by taking advantage of respective strengths and joining forces for gaining market share.

Such arrangements are acceptable so long as no taxpayer dollars go to foreign companies for launch technology development that in turn could be used to

strengthen foreign competitive launch systems. And provided that no U.S. technology is unlawfully transferred out of the country.

Investment By NASA and By Industry. NASA is prepared to pay for the technology work necessary to reduce the risk, with some “earnest money” cost sharing from our corporate partners. The point when we are looking for serious industry investment is after the risk is reduced to an acceptable level, when a customer base--the U.S. Government among them-- can be formed, and private sector capital can finance development, production, and operation of a commercial RLV fleet.

NASA and other space-faring agencies of the Government will be major, continuing customers of successful RLV operators. This business will enable economies of scale and product volume that will permit attractive deals with U.S. domestic and global launch users. This expanded market will enable further economies and margin growth.

Yet, despite the potential future market, NASA is being told by the space industry that some form of Government amortization of commercial development costs, or Government-guaranteed manifesting, tax holiday, or other financial incentive device, is required before venture capital can be raised for full-scale commercial development of the RLV fleet. NASA is examining the need for some type of incentive in this area and looking at feasible options should they prove necessary for full-scale development of the RLV fleet.

Just as NASA has a responsibility to be a smart buyer, we welcome the smart, responsible corporate vendor of launch services. Costs will be radically lower and performance superior in terms of lift, scheduling, quality, and safety. Everyone benefits and well-deserved profits will flow. But the corporate operators/vendors must realize that they are accountable for any lack of performance. The Government must not be expected to cover all risks. Under-capitalized operations, uncertified vehicles, and reliance on “Government-support-no-matter-what” are formulas for failure. And, **the Government, the launch industry, and the overall U.S. space program cannot afford to fail in this endeavor to make access to space affordable.**

A National Team Effort To Effect Change

It is never easy to effect significant change. But we must. The stakes are enormously high: they are no less than the future viability of the nation's space program, enabled by a vigorous, world-class U.S. space launch capability. Radical improvements in performance and cost will directly benefit our national defense, our science and technology for civil space, and

open a new era of commercial development of space. If this nation is to remain a preeminent leader in exploring and utilizing the unique frontiers of space, we must make the changes needed now to achieve the results required in just a few years.

NASA fully accepts its leadership responsibilities in this area, but also realizes the complexities involved. It will take the help and cooperation of many agencies and the private sector to achieve our RLV goals.

Revitalizing U.S. space launch capabilities will require the best from all of us: the best of NASA's expertise and facilities, the coordinated utilization of special expertise and facilities of other space-faring agencies such as the Department of Defense, close interaction with other Federal agencies such as the Departments of Transportation and Commerce and the Office of the U.S. Trade Representative, the best creative genius and entrepreneurial energies of the commercial launch industry, and--not least--the best guidance and support the Congress can provide. The decisions we make collectively and individually will impact the viability of the space program and future American leadership throughout the world.

Thank you, Mr. Chairman, for the support of this Committee. We are ready to work with you in every way to advance this vital national effort.

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